ORGANIC SOLAR CELL EXPLORATORY RESEARCH

GRANT DUPATION: 1 YEAR

GRANT AMOUNT: $75,000

DR. STEVEN J. VALENTY

CORPORATE RESEARCH AND DEVELOPMENT

GENERAL ELECTRIC COMPANY
SCHENECTADY, NEW YORK

PRINCIPAL INVESTIGATOR: DR. S. J. VALENTY

July 22-25, 1975

LOS ANGELES, CALIFORNIA

This experimental program is formulated to obtain an understanding of the principles governing the photovoltaic effect in organic materials on the molecular level, and to apply these principles to the design and fabrication of laboratory devices having a photovoltaic organic polymer film as their key element.

The initial part of the program seeks to understand the mechanism of charge generation and separation in extremely thin (≲50Å) synthetic organic films, in which one side of the film is a light sensitive electron donor (or acceptor) and the other is an electron acceptor (or donor). The approach may be thought of as a way to study the photovoltaic effect of a single organic junction. By adapting techniques of surface chemistry, it has been possible to form such potential photovoltaic junctions. Further, the use of this methodology provides the capability to vary both the composition of the junction (donor, acceptor, donor-acceptor distance, orientation, concentration) and its environment (aqueous redox electrodes, metal electrodes, semiconducting electrodes and bulk organic electrodes). It is expected that the ability to control these many experimental variables will allow a more detailed description of photovoltaic efficiency in terms of light absorption, charge generation, charge separation and charge collection than heretofore.

Progress to date has been in three areas: (1) materials synthesis, (2) apparatus development, and (3) ultra-thin film fabrication. An initial materials synthesis has provided a variety of surface active dyes, primary electron acceptors and polymers needed as prerequisites to film fabrication. Apparatus development includes the design and construction of devices used: (1) to characterize the surface properties of materials at the air-water interface, (2) to fabricate the asymmetric ultra-thin films, (3) to observe the optical absorption and fluorescence spectra of the films, and (4) to measure the electrical properties of the films. Both symmetrical and asymmetrical ultra-thin films of the synthesized materials have been formed and supported on glass slides for optical study.

The current effort is directed at achieving reproducible formation of a free-standing asymmetric film separating two aqueous redox electrodes.

For the first six months of the grant award, the main objective will be a demonstration of the photovoltaic effect in an asymmetric membrane formed using the surface chemistry methodology developed in this program.

Contributing Personnel: Dr. G. L. Gaines, Jr.
Dr. S. J. Valenty

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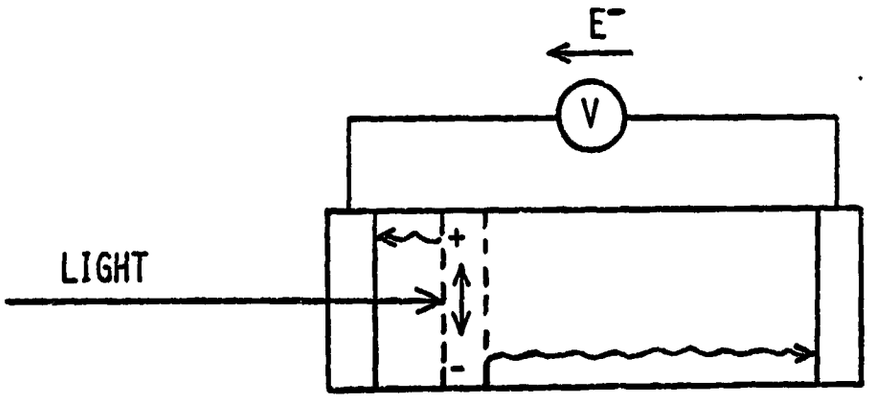
OVERALL OBJECTIVES OF PROJECT

- EXPERIMENTAL DETERMINATION OF THE MAJOR FACTORS GOVERNING THE PHOTOVOLTAIC EFFECT IN ORGANIC MATERIALS ON THE MOLECULAR LEVEL

- THE DESIGN AND SYNTHESIS OF A NEW CLASS OF ORGANIC PHOTOVOLTAIC POLYMERS AND THEIR FABRICATION INTO LARGE AREA SOLAR CELLS

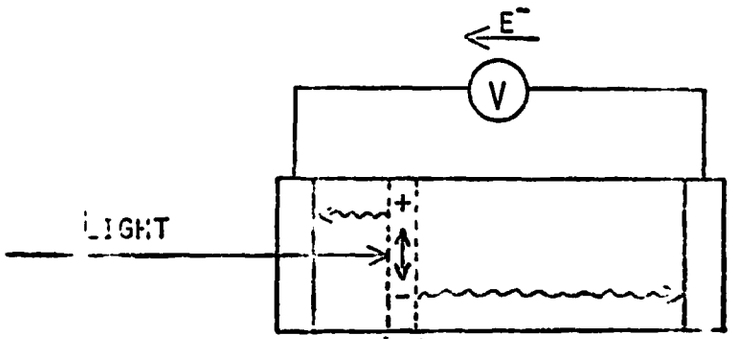
PHOTOVOLTAIC EFFICIENCY IN ORGANIC MATERIALS

$$\text{EFF} \propto \text{LIGHT ABSORPTION} \bullet \text{CHARGE GENERATION} \bullet \text{CHARGE MOBILITY} \bullet \text{CHARGE COLLECTION}$$

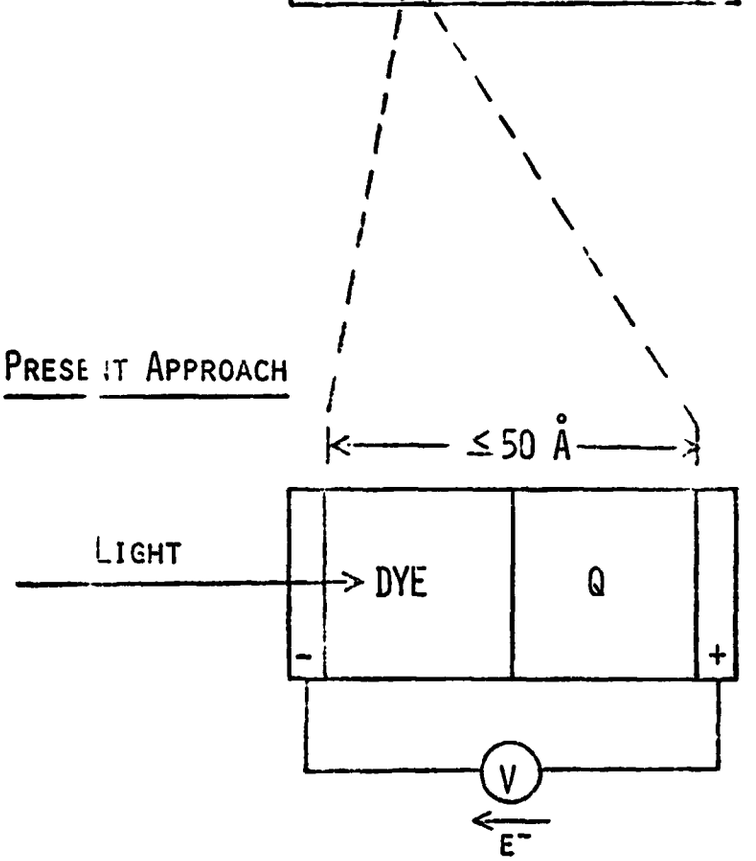


"SINGLE JUNCTION" vs. "CLASSICAL" APPROACH

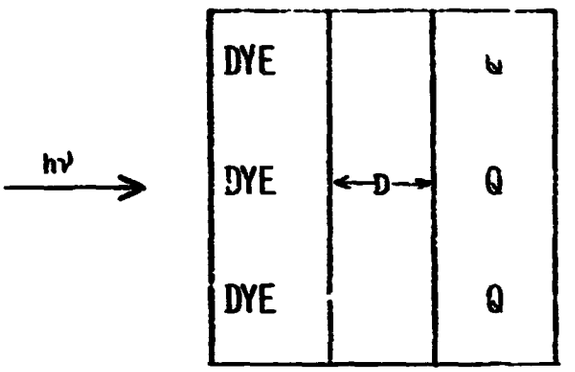
"CLASSICAL" APPROACH



PRESENT APPROACH



SINGLE ORGANIC JUNCTION EFFICIENCY CONSIDERATIONS



$$DYE + h\nu \xrightarrow{K_{h\nu}} DYE^{*}$$

$$DYE^{*} + Q \underset{K_R}{\overset{K_T}{\rightleftharpoons}} DYE^{+\cdot} + Q^{-\cdot}$$

$$DYE^{*} \xrightarrow{K_f,\ K_Q} DYE + h\nu' \text{ OR } \Delta$$

I

LIGHT FLUX

V

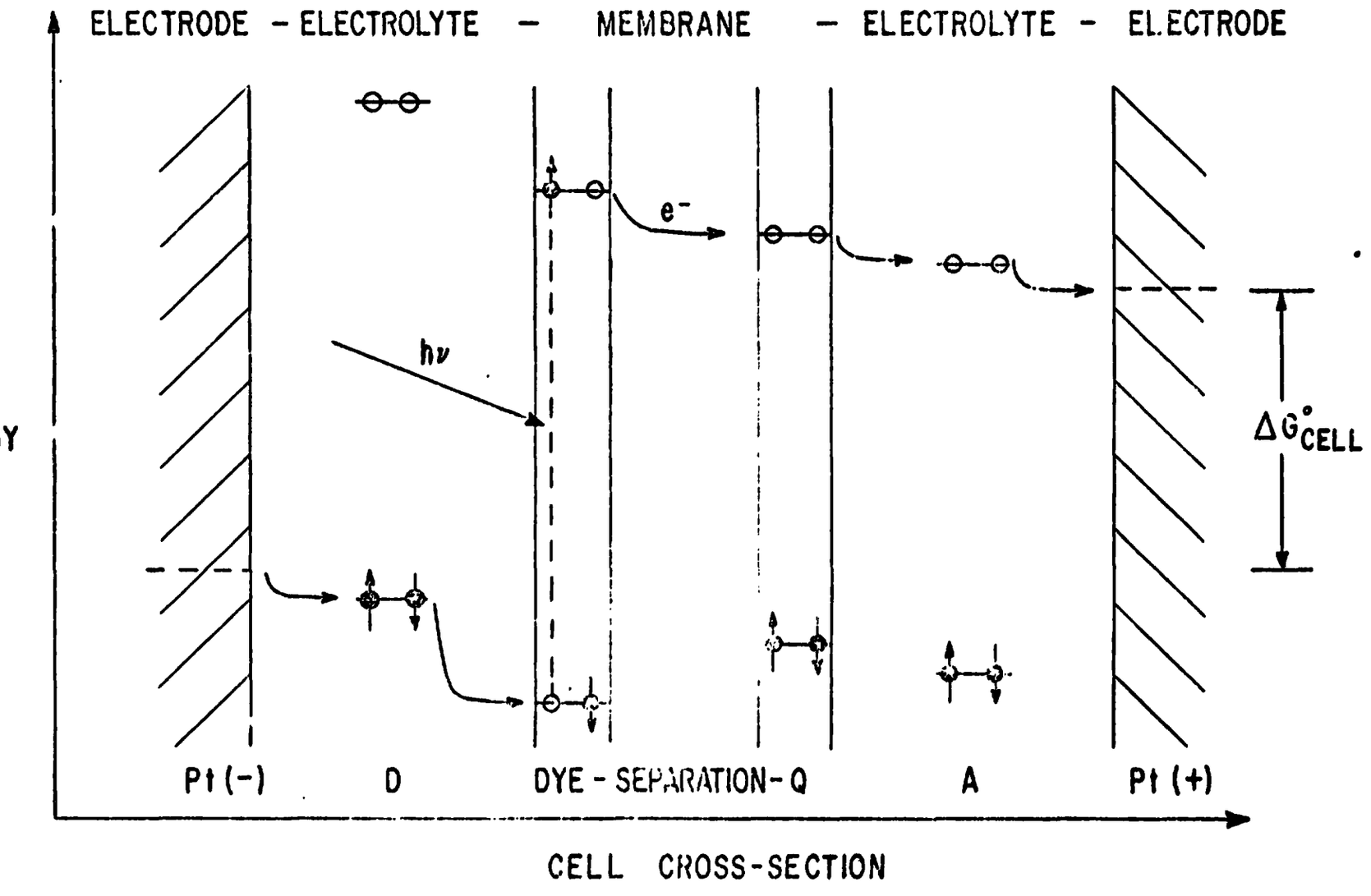
$\Delta G_{DYE^{*},Q}$

TUNNELING EFFICIENCY

$K_T \propto \text{EXP}\left[D \times (V-E)^{1/2}\right]$

COMPETING PROCESSES

RECOMBINATION



ENERGY LEVELS OF CELL COMPONENTS WHEN ILLUMINATED

PROGRESS TO DATE

- MATERIALS SYNTHESIS
- APPARATUS DEVELOPMENT
- ULTRATHIN FILM FABRICATION

MATERIAL SYNTHESIS

ULTRA-THIN FILM FABRICATION REQUIRES SURFACE ACTIVE MATERIALS

- DYES

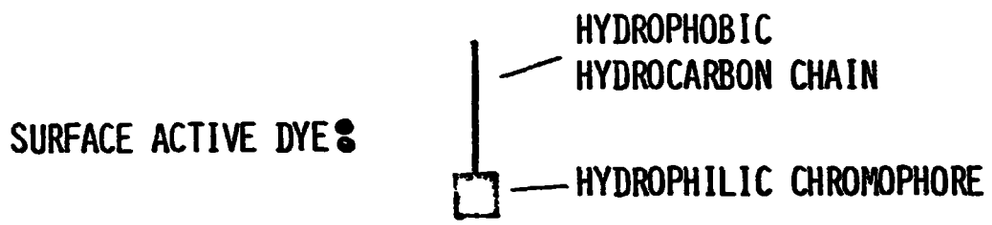
  THIAZINE, AZINE, ACRIDINE

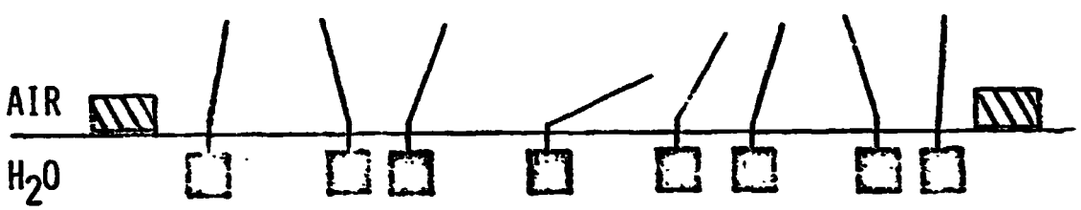
- PRIMARY ELECTRON ACCEPTORS

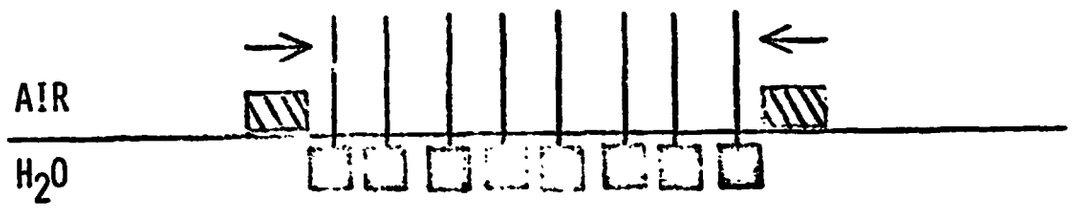
  QUINONE, VIOLOGEN

- SURFACE ACTIVE POLYMERS

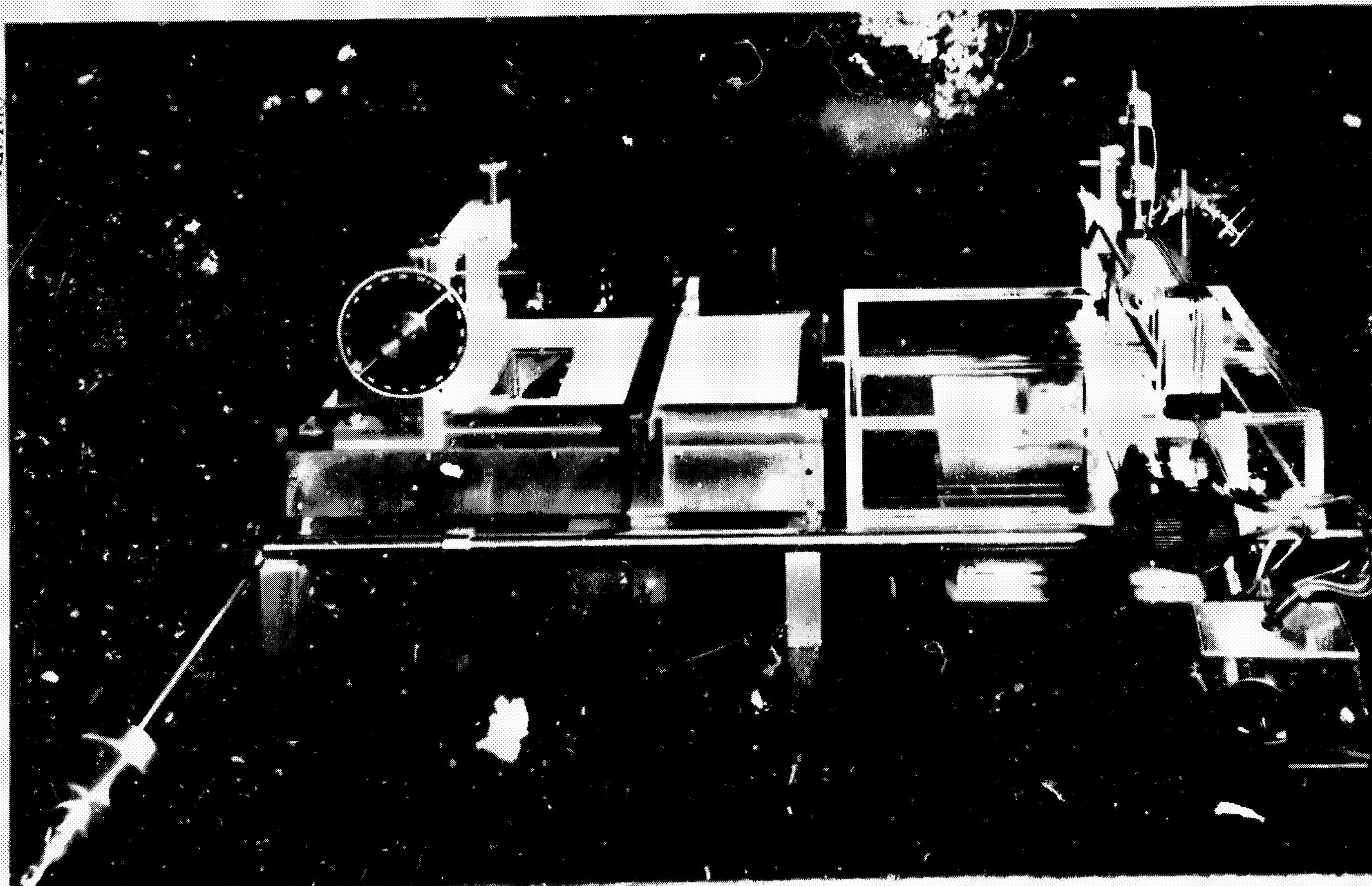
INSOLUBLE MONOLAYERS AT AIR-H_2O BOUNDARIES



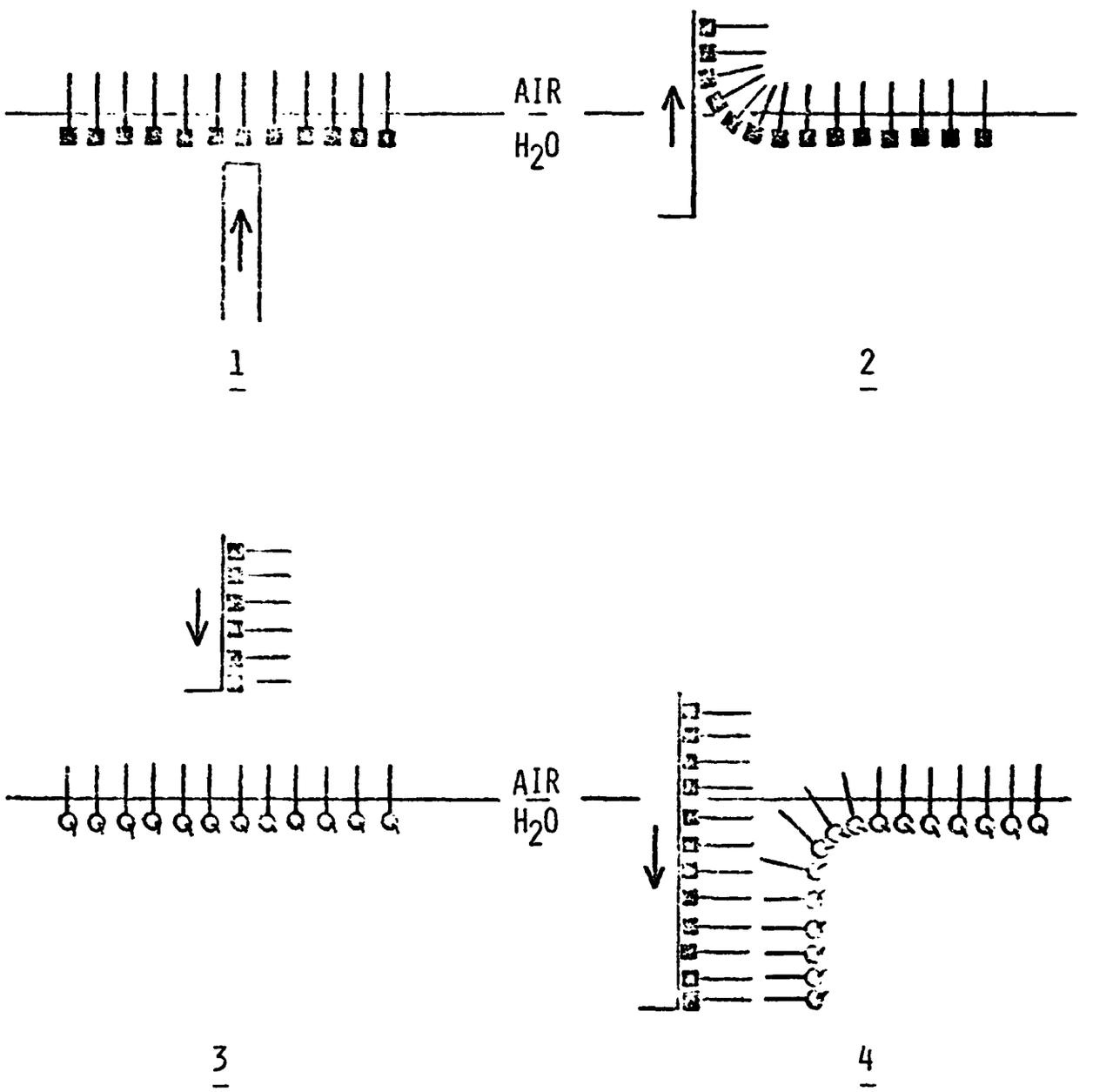


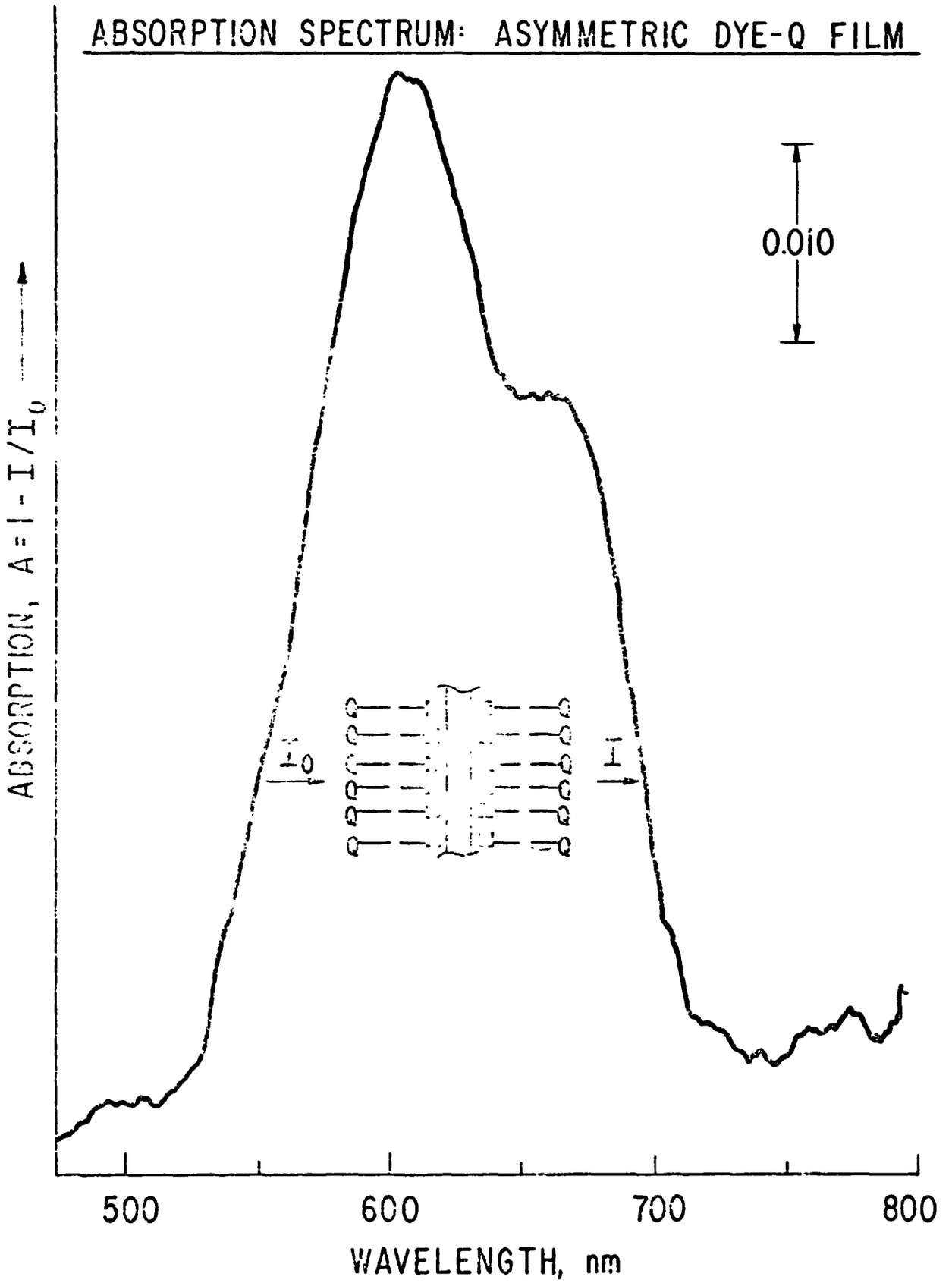


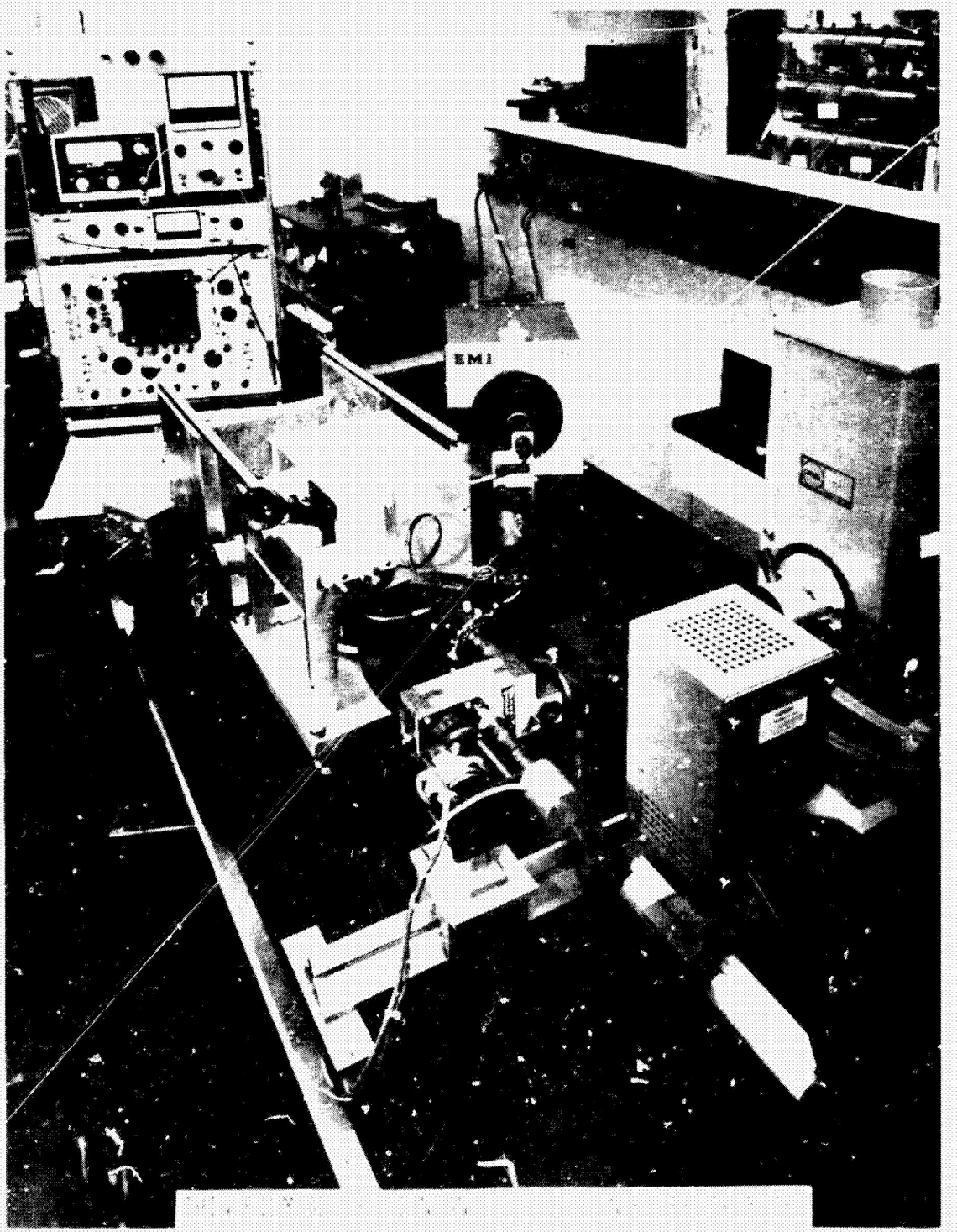
MONOLAYER TROUGHS, FILM BALANCE AND DIPPING MECHANISM



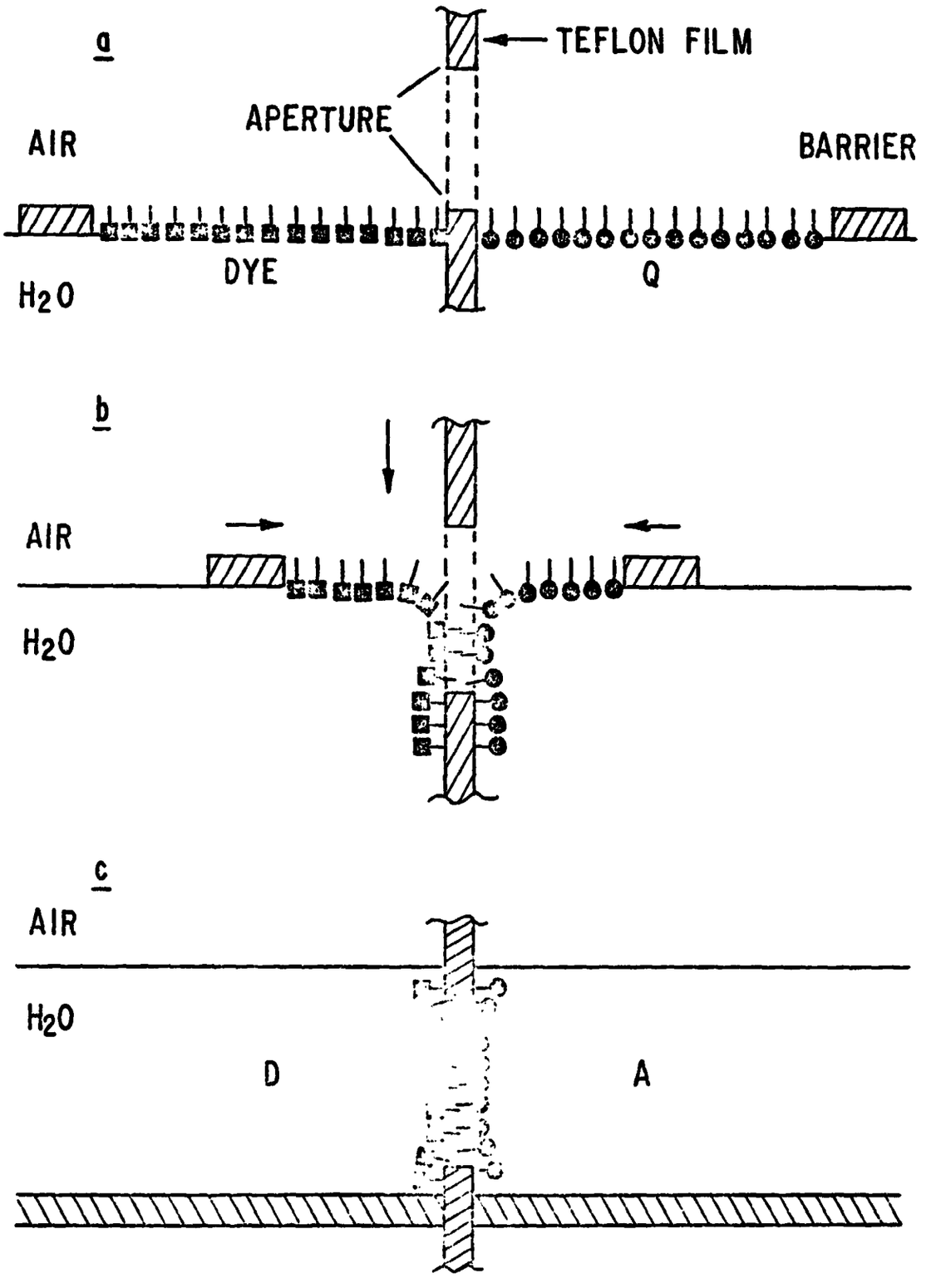
ASYMMETRIC FILM FABRICATION ON SOLID SUPPORTS

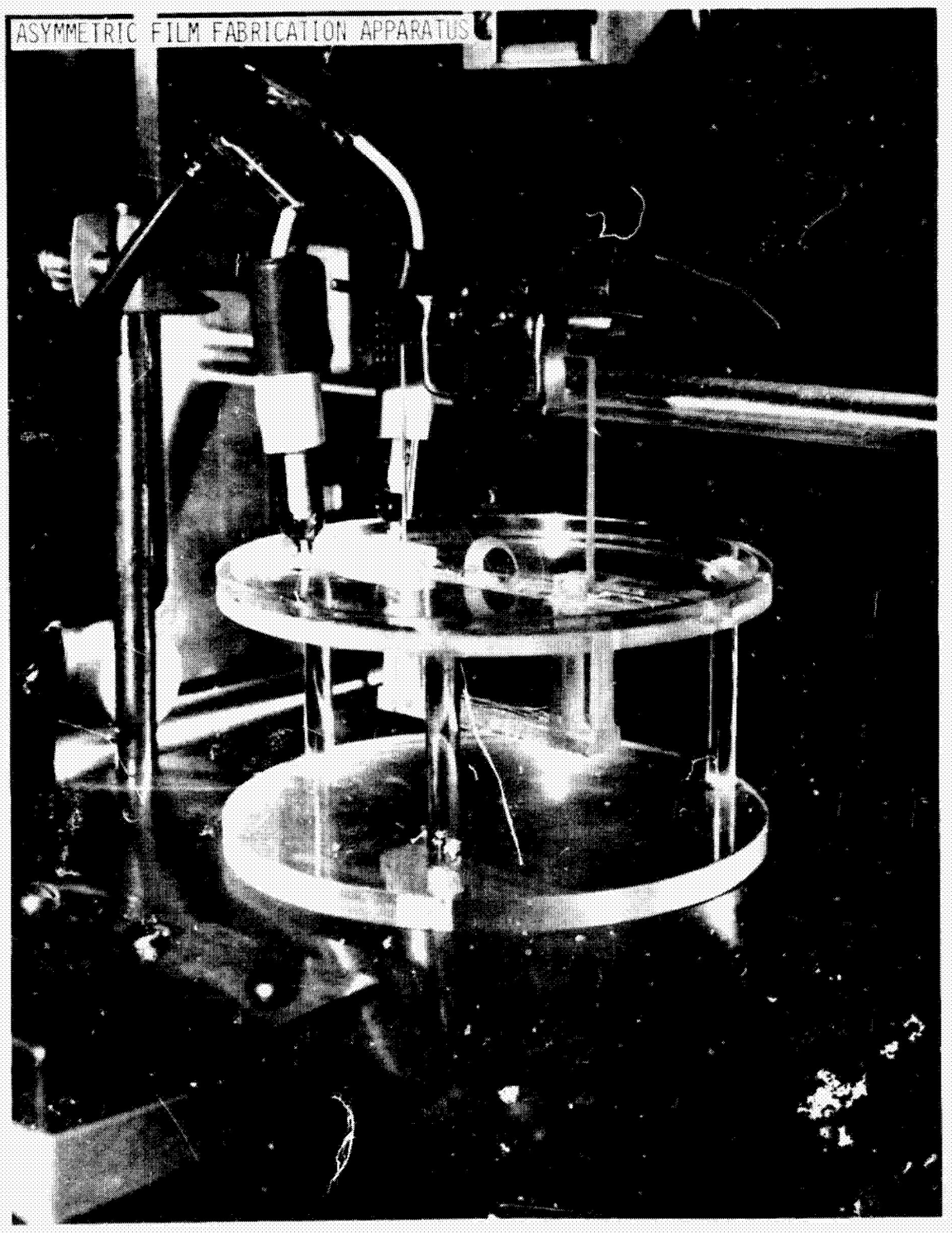



ABSORPTION SPECTRUM: ASYMMETRIC DYE-Q FILM
0.010
ABSORPTION, A = 1 - I/I0
I0
I1
500
600
700
800
WAVELENGTH, nm



ASYMMETRIC MEMBRANE FORMATION





SUMMARY OF KEY RESULTS

1) APPARATUS DEVELOPMENT -- COMPLETED

ABSORPTION/FLUORESCENCE SPECTROMETER
LANGMUIR FILM BALANCES AND MONOLAYER TROUGHS
ASYMMETRIC FILM TROUGH
VOLTAGE AND CURRENT CLAMPING CIRCUITRY

2) INITIAL MATERIALS SYNTHESIS -- COMPLETED

SURFACE ACTIVE DYES, Q AND POLYMERS

3) SUPPORTED ASYMMETRIC FILMS

SPECTROSCOPIC STUDIES

MAJOR PROBLEMS

- FABRICATION OF FREE-STANDING ASYMMETRIC ULTRA-THIN MEMBRANES INTO COMPOSITE FILMS OF ADEQUATE MECHANICAL STRENGTH

- NEED TO DISCOVER EFFICIENT ELECTRON TRANSFER REACTIONS TO UTILIZE ALL THE POTENTIAL ENERGY PRODUCED IN THE ILLUMINATED FILMS

PLANNED ACTIVITY FOR NEXT 6 MONTHS

DEMONSTRATION OF THE PHOTOVOLTAIC EFFECT IN AN ASYMMETRIC MEMBRANE

- MEMBRANE FABRICATION
- PROOF OF MEMBRANE STRUCTURE
- CHOICE D AND A
- WAVELENGTH DEPENDENCE OF OPEN CIRCUIT EMF
- OPEN CIRCUIT EMF AND DYE FLUORESCENCE INTENSITY AS A FUNCTION OF DYE, Q, A, D CONCENTRATION AND pH
- OPEN CIRCUIT EMF AS A FUNCTION OF LIGHT INTENSITY
- I-V CHARACTERISTICS